sketches of New Zealand, New Britain, New Guinea, and the Caroline Archipelago are exceedingly well drawn and valuable. He brings about 100 cases of ethnographical specimens intended for the new Ethnological Museum at Berlin.

THE AIMS AND METHOD OF GEOLOGICAL INQUIRY[1]

IN entering upon the duties of this Chair I can hardly do better, perhaps, than try to set before you what are the primary aims and general bearings of that branch of natural science which we are about to study, and to indicate the nature of the problems with which it deals. In doing so I will endeavour at the same time to point out the method of research and the mode of reasoning which we must pursue if we are to be successful investigators. Geology (in which comprehensive term I include mineralogy and palæontology), is concerned in the first place with observations of minerals, rocks, and fossil organic remains, and in the second place with the inferences which may be drawn from those observations. Its object is thus not only to note the nature and position of the various materials which constitute the solid crust of our globe, but by processes of inductive and deductive reasoning to ascertain how minerals and rocks have been formed and caused to assume the different appearances which they now present. In few words, then, our science might be defined as an inquiry into the history or development of the earth's crust, and of the several floras and faunas which have clothed and peopled its surface. It thus treats of the genesis of oceanic and continental areas—of mutations of climate—of the appearance and disappearance of successive tribes of plants and animals. More than this, in revealing the past it throws strong light upon the present, and has, perhaps, more than any of the cognate sciences, tended to revolutionise our conceptions of nature, and to lead zoologists and botanists into fruitful fields of inquiry which their own proper studies, no matter how assiduously prosecuted, could never have enabled them to reach.

Dealing, as geology does, with the operations of Nature in the past, it is obvious that before we proceed to interpret the record of the rocks we ought to have a clear knowledge of the mode in which Nature works at present. Without this preliminary knowledge, it is just as hopeless to attempt to decipher that record as it would be to endeavour to understand a page of Greek without having first mastered the grammar and rudiments of that language. We must turn our attention then, at the very outset, to a study of those great forces by the action of which the crust of our globe is being continually modified. It is essential that we learn to appreciate the work done by the atmosphere, by frost and snow and ice, by rain and underground water, by rivers and lakes, by the sea, by plants and animals, and by the subterranean forces, before we can hope to recognise the different parts which those various agents of change have performed in the past. All geologists are agreed upon this, and are ready to acknowledge it as the chief article of their faith. Nevertheless, this obligatory article has received different interpretations. Some, for example, have held that the present condition of things must be taken as the exact type of all the phases through which the earth's surface has passed, during the different stages of which we have any recognisable records preserved to us in the stratified rocks of the globe. They admit that countless modifications of land and sea have taken place—that the climate of particular areas has varied again and again—that the subterranean and volcanic forces have manifested themselves with unvarying intensity, now in one place, now in another—but they hold that all these changes have been accomplished upon the same scale and at the same rate as at present, and that, as a consequence, the development of floras and faunas, so far as that is dependent upon physical conditions, has proceeded no more rapidly in former times than in our own day. They do not, indeed, deny that in the very earliest stages of the earth's history the agents of geological change must have acted with greater intensity than now, but of such a period, they tell us, we have no certain evidence treasured up in the sedimentary rocks, or at least such evidence, if it should exist, has not yet been detected. Only allow time, they say, and the constant drop will wear away the hardest stone. The gradual elevation of land, which is now going on in certain parts of the globe at so slow a rate that some have been inclined to doubt whether there is any movement at all, would nevertheless suffice in time to lift tracts now within tide-wash into stupendous table-lands and mountains. Nor is it necessary, we are assured, to suppose that the apparent evidence of convulsive rending and displacement of strata, which is often so conspicuous in the heart of great mountain-chains and ranges, is really any proof of paroxysmal action. All the rupturing and confusion which we may note among the Alps and not a few mountain-regions, may quite well have been brought about, we are informed, in the most gentle and gradual manner.

Other theorists, again, are of opinion that, while the agents of change have necessarily been through all time the same in kind, they have yet varied again and again in degree, and that the present moderate condition of things cannot therefore be taken as an exact type and pattern of all preceding phases in the world's history. They cannot allow that the elevation of mountain-chains and the larger fractures and displacements of strata are the result of the repetition of such small movements of the crust as are taking place now. Admitting that considerable areas of the earth's surface are rising at the rate of a yard or more in a century, they yet cannot agree that this is a criterion by which to estimate the time required for the elevation of all protuberant parts of the earth's crust. They remind us that in our own day we have had experience of paroxysmal changes of level, nor can they doubt that similar sudden catastrophes must have happened oftentimes in the lapse of ages. They point to the appearance of ruin and confusion which may be traced along a line of mountain-elevation, and maintain that the broken and shattered strata are proofs of a more or less sudden yielding to enormous strain or tension. They do not deny that upheaval may have been going on over a given area at an extremely slow rate during long periods of time, but they argue that a point would at last be reached when the tension to which the strata were subjected could no longer be resisted. A sudden fracturing would at last take place—the strata would be violently dislocated, thrust forward, crumpled, and heaped, as it were, in confused and steeply-inclined masses along the main line of dislocation. Again, it is objected to uniformitarian views that these do not explain and cannot account for certain remarkable mutations of climate which are known to have occurred. It is not denied that the earth has been receiving for untold ages the same annual amount of heat from the sun, but it is maintained that, owing to certain astronomical changes, and the modifications induced thereby, that heat must have been very differently distributed over the globe at various epochs in the past. It is held, in short, that the climate both of the northern and the southern hemispheres has thus been frequently modified, and that in consequence of this the action of the geological agents has been influenced again and again—the decay and reconstruction of rocks the oscillations of the land—and the development of floras and faunas having been alternately accelerated and retarded according as extreme or moderate conditions prevailed.

Thus each school has its own method of interpreting the fundamental axiom of our science—that the Present is the key to the Past. And as the primary aim of geology is to interpret the stony record with a view to the reconstruction of our earth's history, it is obviously important that we should be able to satisfy ourselves as to which of these rival conceptions is most consonant with truth. In other words, we must do our utmost to ascertain which gives the most reasonable interpretation of geological phenomena. Each view must in its turn be tested by an appeal to facts, and a rigorous application of logical analysis. Probably we shall find that while there is much to be said on both sides, we can agree entirely neither with the one school nor the other. Before we are in a position, however, to discuss such questions, we must first have ranged over a very wide field of inquiry, and obtained a thorough grasp of the principles of our science.

Meanwhile, our chief concern in beginning our studies must necessarily be to detect resemblances between the present and the past. For every observation we make we must endeavour to discover a correlative phenomenon in the present order of things. And so long as we confine our attention to the facts before our eyes and to the more obvious interpretations of these which are suggested by forces now in action, we shall not fail to be impressed with the uniformity of nature.

We examine, let us suppose, a section of strata exposed upon the sea-shore or along the banks of a river. Our knowledge of the different kinds of sediment in course of transportation and

[1] The Inaugural Lecture at the opening of the Class of Geology and Mineralogy in the University of Edinburgh, October 27, 1882, by James Geikie, LL.D., F.R.S. L. and E., Regius Professor of Geology and Mineralogy in the University.

accumulation at the present day enables us at once to recognise, in the conglomerate sandstone and shale of our section, simply the consolidated sediments of earlier times. The occurrence of fossils in the strata determines whether the deposits were formed in fresh water, brackish water, or the sea—whether near to a coast-land, or at a greater distance from the shore, and so forth. If some of the fossils be of terrestrial origin, while others are brackish- water and marine, we gain not only certain knowledge of the life of the period, but, if the evidence be full enough, we may even form more or less reliable conclusions as to the physical and climatic conditions which at one time existed in the locality under our examination. In short there are many almost obvious conclusions, as we may term them, which the appearances presented by an individual exposure of rocks must suggest to any observer who has previously become familiar with the operation of the natural forces in the world around us. He simply compares the facts with what is now taking place, and is thus led to conclude that effects the same in kind have been produced in the same way.

Sometimes, however, the rocks present appearances which are harder to interpret in this obvious and ready manner. We encounter, for example, a rock-mass having none of the features presented by ordinary sedimentary strata. Instead of being made up, like conglomerate and sandstone, of rounded stones or grains, arranged in layers, it is entirely composed of larger and smaller crystalline particles, not lying in lines and layers, but scattered indiscriminately through the whole mass. It does not occur in beds like ordinary sedimentary strata, but on the contrary we see it cutting, as it were, across other rocks, and sending ont veins which penetrate the latter in all directions. The observer immediately concludes that the crystalline rock is of younger age than the beds traversed by it; and not only so, but that the whole mass with all its veins was injected into its present position in a liquid, semi-liquid, or pasty, and probably heated condition. And in confirmation of this last conclusion he may perhaps note that the rocks immediately adjoining the dykes and veins betray the appearance of having been subjected to the action of heat. The grits, we shall suppose, are hardened and much cracked and shattered, and the shales baked and porcellanised; both rocks, when closely examined, showing traces of an incipient fusion along the line of contact with the intrusive rock. They may even lose their original granular texture, and assume a more or less crystalline aspect for some distance away from the dykes and veins that intersect them. All these features the observer may have seen exemplified in a modern volcanic district, and he may therefore feel justified in the opinion he has formed as to the formerly molten state and therefore igneous origin of our crystalline rock. His induction, however, is not complete. He compares his supposed igneous rock with the undoubted products of existing volcanoes, and although many of these last send out dykes and veins, and have a crystalline texture, yet not a single one may have any further resemblance to the crystalline rock of his section. He cannot, therefore, be any longer certain that his dykes and veins have originated in the same way as those of Etna and Vesuvius. The origin of such a crystalline rock as I am speaking of (which we may suppose is granite), cannot be determined, like that of conglomerate or sandstone, by direct comparison with similar rocks in process of formation. Exhaustive examination of the granite itself, an intimate knowledge of its ingredients, and the conditions of formation which these imply, combined with careful observation of the mode in which this rock occurs wherever it is met with—these and other studies must be prosecuted before any assurance can be obtained as to the precise mode in which granitic dykes and veins have originated. The observer then learns that these are really of igneous origin, as he at first inferred, but his notion that they have been injected into strata at or near the surface like the dykes of modern volcanoes, cannot, he finds, be maintained. All the evidence supplied by careful microscopical examination and physical considerations, leads to the conclusion that granite has been formed and consolidated at considerable depths. Having satisfied himself upon this point, the observer will readily conclude that the dykes and veins that now appear at the surface were formerly buried under great masses of rock, which have since been removed. Of course there are many *other* facts connected with the history of granite which I do not touch upon at present. By and by we shall learn that all masses of granite are not intrusive, but that certain considerable areas of this rock, although agreeing in composition with the granite of dykes and veins, are nevertheless not irruptive.

The conclusion that granite is of deep-seated origin is not, you will observe, contrary to our canon that the past is to be interpreted by the present. Molten rock, as we know, is forced into fissures in the neighbourhood of active volcanoes, and there consolidated, and chemical analyses show that some volcanic rocks have the same ultimate composition as granite. Partly by observation and partly by experiment we detect in granite evidence to prove that it has consolidated under pressure, and that, had the original molten mass cooled more rapidly and under moderate pressure, the resulting rock would have presented a very different appearance. Had injection taken place at or near the surface, or had the melted matter flowed out of a volcanic orifice, it might well have resembled some of the products of modern volcanoes.

Let us now take another sample of the mode of interpreting geological phenomena. We shall go back to our section of conglomerate, sandstone, and shale—and these deposits we shall suppose belong to a comparatively recent date—to the Tertiary period, let us say. Suppose, moreover, that the fossils are numerous, and so well preserved that we are enabled to compare them with living forms. A few, we find, belong to existing species, others are closely related to these, while yet others, although without doubt extinct, can nevertheless be referred with confidence to living genera. These facts enable us to come to a trustworthy conclusion as to former climatic conditions, for all we have to do is to examine the conditions under which the existing species presently flourish, and draw the obvious inference. Of course the larger the number of living species, and the more highly organised these are, the more reliable our theoretical results will be. But suppose our fossils indicate a warm and genial climate, and that the locality in which we discover our section lies far within the Arctic Circle—what must our conclusion be? Simply this: that the climate of those high latitudes was formerly much warmer than it is now. We appeal to the present, and that is the reply we get. But the next question arises: How could such a climate obtain within the Arctic Circle? This is one of those crucial cases which must eventually determine whether Uniformitarians are justified in maintaining that the present is the exact type of all that has gone before, within known geological periods. According to them it is not necessary to look beyond this earth itself for an explanation of such an apparent anomaly as the occurrence of southern faunas and floras in the Arctic regions. All we have to assume, they tell us, is a former very different distribution of land and water. They refer us to the well-proved fact that there have been freqnent considerable elevations and depressions of the land, which must have indirectly affected the climate of wide areas by modifying the course of oceanic and aërial currents. They argue that were the larger land-areas of the globe to be grouped about the equator, with oceanic islands scattered over the higher latitudes, this arrangement of land would induce all the conditions that are necessary to account for the former growth of walnuts and oaks and beeches within the Arctic Circle.

This hypothesis is opposed by others who maintain that no such distribution of land and water existed at the epoch in question. According to them, the position of the main continental ridges and oceanic depressions was established at a very early period in the earth's history. The persistence of these main features, however, does not imply a total invariability of outline. On the contrary, the protuberant areas, it is admitted, have been modified again and again all through the geological ages—considerable portions having been alternately depressed below and lifted above the sea-level. But as the relative positions of the more important ridges and depressions of the earth's surface—the continental areas and oceanic basins—were determined long anterior to the deposition of the Tertiary strata, and probably date back to azoic times—such a re-arrangement of land and sea as the Uniformitarian view requires cannot have taken place. It is further maintained that, even could such a re-arrangement be substituted for the present, it would not bring about a genial climate in the Arctic regions. We must look beyond our globe itself, we are told, if we wish to find the key to those greater revolutions of climate of which we have evidence in such a case as the occurrence of a southern flora within the Arctic Circle. The greater climatic revolutions of the past are due, we are assured, to periodical changes in the eccentricity of the earth's orbit, combined with the precession of the equinoxes, and the influence which such mutations must have exerted upon the ordinary agents of geological change.

The soundness of these opposing views must of course be

tested by an appeal to facts, and it will be our duty in the course of our investigations to examine all the data which have been adduced in their support. I have referred to them on this occasion merely to show you that above and beyond the more or less obvious interpretation of geological phenomena, larger questions arise, the consideration of which demands not only laborious and far-extended observation, but must call into exercise all the varied powers of the human mind.

In the initial stages of our geological investigations we are occupied in detecting the more apparent resemblances and correspondences between the present and the past. We readily discover in sedimentary strata the evidence of their accumulation by the action of water, nor do we experience much difficulty in discovering the igneous origin of many rock-masses in regions now far removed from scenes of volcanic activity. But each observation we make and every well-founded correspondence we establish between the present and the past leads on to larger and larger deductions, until, as in the case of our granitic dykes and veins, we eventually find that geological investigations frequently increase our acquaintance with forces now in action and give us some insight into the hidden operations of nature. It is not indeed too much to say that in many cases our knowledge of such operations is derived in large measure from a study of the effects produced by the work of nature in past ages. The examination, for example, of the fragmentary relics of ancient volcanoes, in this and other countries where volcanic action has long been extinct, has enabled us to picture to ourselves many details of the structure of those interior and basement parts of a volcanic mountain, which otherwise must ever have remained unknown. The long-continued action of the agents of denudation has often removed those superficial rock-masses which gather around volcanic orifices, so as to lay bare, as in a dissection, the interior and basal portions—showing us the fractured and baked strata through which the heated gases, molten matter, and loose ejectamenta were erupted, and the dykes and veins of crystalline rock which were injected into the cracks and fissures of the shattered strata. Nay, a study of those vast masses and sheets of granitic, gneissose, and schistose rocks, of which large portions of the Scottish Highlands, Scandinavia, and other countries are composed, induces the belief that these rocks originally existed as ordinary sedimentary strata, and that their present crystalline condition has been assumed at a time when they were deeply buried underneath other and of course younger strata. And thus we have hints given us as to what may be taking place now throughout extensive areas underneath the surface of the earth, where other sandstones and shales may be undergoing a gradual metamorphism and conversion into crystalline rocks.

(*To be continued.*)

THE SENSES OF BEES

At the meeting of the Linnean Society on Thursday last, Sir John Lubbock read an account of his further observations on the habits of insects, made during the past year. The two queen ants which have lived with him since 1874, and which are now, therefore, no less than eight years old, are still alive, and laid eggs last summer as usual. His oldest workers are seven years old. Dr. Müller, in a recent review, had courteously criticised his experiments on the colour sense of bees, but Sir John Lubbock pointed out that he had anticipated the objections suggested by Dr. Müller, and had guarded against the supposed source of error. The difference was, moreover, not one of principle, nor does Dr. Müller question the main conclusions arrived at, or doubt the preference of bees for blue, which indeed is strongly indicated by his own observations on flowers. Sir John also recorded some further experiments with a reference to the power of hearing. Some bees were trained to come to honey which was placed on a musical box on the lawn close to a window. The musical box was kept going for several hours a day for a fortnight. It was then brought into the house and placed out of sight, but at the open window and only about seven yards from where it had been before. The bees, however, did not find the honey, though when it was once shown them, they came to it readily enough. Other experiments with a microphone were without results. Every one knows that bees when swarming are popularly, and have been ever since the time of Aristotle, supposed to be influenced by clanging kettles, &c. Experienced apiarists are now disposed to doubt whether the noise has really any effect, but Sir John suggests that even if it has, with reference to which he expressed no opinion, it is possible that what the bees hear are not the loud low sounds, but the higher overtones at the verge of, or beyond our range of hearing. As regards the industry of wasps, he timed a bee and a wasp, for each of which he provided a store of honey, and he found that the wasp began earlier in the morning (at 4 a.m.), worked on later in the day. He did not, however, quote this as proving greater industry on the part of the wasp, as it might be that they are less sensitive to cold. Moreover, though the bee's proboscis is admirably adapted to extract honey from tubular flowers, when the honey is exposed, as in this case, the wasp appears able to swallow it more rapidly. This particular wasp began work at four in the morning, and went on without any rest or intermission till a quarter to eight in the evening, during which time she paid Sir John 116 visits.

INVERTEBRATE CASTS VERSUS ALGÆ IN PALÆOZOIC STRATA

The distinguished Swedish geologist, Dr. A. Nathorst, having made numerous experiments, has come to the conclusion that invertebrate animals, when creeping over a soft sea-bottom, will leave imprints which are identical with the markings which have hitherto been considered those of fossil Algæ. If these Algæ are examined, it will be found, he states, that the appearance of a great many of them indicate that they have not been organisms at all, but formed in some mechanical way, and that analogous forms may even be found in existing species.

Dr. Nathorst considers that with the exception of three groups, the greatest number of Algæ enumerated in Mr. Schimper-Zittel's work on Palæontology as "undefined," are merely imprints of invertebrate animals.

Some time ago Prof. Martens of Berlin demonstrated that ichthyological members of the genus *Periophtalmus* which he had watched on the coast of Borneo when creeping over a clay bottom, left regular and defined impressions from their body and fins on the surface which would, if preserved, easily be mistaken for cryptogamic fossils, and in a paper on casts of Medusæ in the Cambrian strata of Sweden, Dr. Nathorst further shows that the so-called *Eophyton spatangopsis*, &c., which have been considered imprints of certain zoophytes and mollusks, are traces of Medusæ. These "fossils" are, according to his theory, either traces which Medusæ leave when carried by the motion of the water over a soft bottom (*Eophyton*), or imprints of their belly and adjacent organs when at rest. He further shows, that a more solid kind of Medusæ than the common have left traces in the calcareous slate of Central Germany, which makes it possible, in some measure, to define their relation to existing species.

Hitherto, Medusæ have only been traced back to the Jurassic period, but Dr. Nathorst shows that these organisms have existed from at least Cambrian times. The imprints which the lower organisms leave on mud or sand vary in appearance with the creeping or swimming habits of the animals, as well as with the nature of the bottom, whilst it is particularly interesting to note that certain worms produce imprints and vermiculated holes, which are exactly like the radiant Algæ, and which would not be supposed to be the work of invertebrata, if their formation had not been clearly demonstrated.

In connection herewith it should be mentioned, that imprints may also be made in a soft sea-bottom by stones, which are carried along with the tide by floating sea-weeds, regarding which observations have recently been made by the Scottish naturalist, Mr. Symington Grieve. C. S.

BIOLOGY IN ITALY[1]

In welcoming the appearance of this new journal under the editorship of Prof. Emery, of Bologna, and Prof. Mosso of Turin, it may not be amiss to mention briefly the programme of its originators. They will endeavour each year to give a classified list of all works published in Italy on biology, in its widest sense. The list for 1881, with an index of the names of authors, appears in volume I. They will try and bring together and illustrate original memoirs on subjects which treat of life in every form. In addition to these there will from time to time appear *résumés* and notices of memoirs appearing in other Italian journals; and as far as practicable the *résumés* will be drawn up by the authors of the papers abstracted. The archives will be

[1] "Archives Italiennes de Biologie," tome i., 1882. Tome ii. fasc. i., October 15, 1882. (Rome, Florence, Turin: H. Loescher.)